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INTRODUCTION TO D.C. POWER INSTALLATIONS

Page

1. INTRODUCTION

1.1 A D.C. power installation is one in which the power supplied to the telecom equipment racks or units is D.C. Except for small installations where a break in the power supply can be tolerated, most D.C. power installations are classified as D.C. no-break systems with either one or two standby supplies.

1.2 To avoid interruption of power supplies, and consequently the communication network, it is essential that staff responsible for power equipment maintenance and installation be thoroughly conversant with the relevant techniques and manual switching operations, before proceeding to work on a power installation.

1.3 Although most telecom D.C. power supplies are at relatively low voltages, much of the equipment at D.C. power installations carries or controls dangerous A.C. voltages. For this reason, it is essential that all relevant safety precautions be strictly observed when inspecting, installing, or carrying out maintenance on these installations.

1.4 The objective of this paper is to describe the basic principles of typical D.C. power installations. The paper "Introduction to Telecom Power Plant" introduces the subject of telecom power supplies and should be thoroughly understood before proceeding with this paper.

2. MAINS POWERED INSTALLATIONS

2.1 GENERAL. D.C. power installations can be classified into mains and non-mains installations. The mains powered stations can be further subdivided into permitted break installations, no-break installations with one standby supply, and no-break installations with two standby supplies.

The permitted break installation provides a D.C. supply by converting the A.C. mains supply to D.C. by means of a rectifier set (sometimes referred to as a battery eliminator when used in this type of installation). The permitted break installation is converted to a no-break installation by the connection of a standby supply in the form of a secondary battery in parallel with the output of the rectifier set. Both these installations are relatively simple and are used at stations where the power requirements are low.

Most of this paper is devoted to describing the principles of the more complex D.C. no-break installation with two standby supplies (achieved by the addition of an N.S. set). This installation is used in situations where a twenty four hour reserve capacity cannot economically be provided by batteries. The principles of operation of rectifier sets and batteries described also apply to the smaller installations. A typical non-mains installation is described in section 5 of this paper.

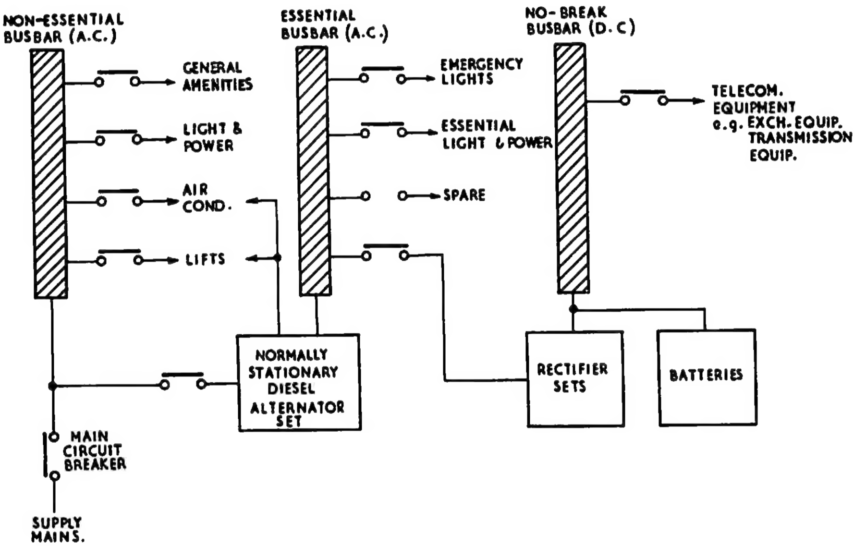


FIG. 1. TYPICAL MAINS POWERED D.C. NO-BREAK INSTALLATION.

2.2 TYPICAL MAINS POWERED D.C. NO-BREAK INSTALLATION (BLOCK DIAGRAM). Fig. 1 shows the block diagram of a typical D.C. no-break installation with two standby supplies. The station load is divided into three categories:

- Non-Essential load. This is an A.C. load comprising equipment which will not cause dislocation of communication services even when the power supply is interrupted for lengthy periods.
- Essential load. This is another A.C. load, the main component of which is rectifier sets which in turn supply the D.C. no-break load. The equipment included in this load can withstand a short duration interruption to its power supply without causing dislocation of communication services.
- No-break load. This is a D.C. load which comprises the various telecom equipment requiring a D.C. no-break supply. A break in the power supply to equipment included in this load causes serious dislocation of communication services.

The distribution busbars (or cables) for the three classes of load are referred to as non-essential, essential, and no-break busbars.

2.3 OVERALL OPERATION. Fig. 1 shows that, under normal circumstances, the non-essential and essential loads are supplied from the mains. The connection to the essential busbar is taken via the control cubicle of the normally stationary set, where facilities are provided to change over to the diesel alternator supply when the mains supply fails. The D.C. no-break load is supplied from the output of rectifier sets which in turn are supplied from the essential busbar.

When the rectifier set output voltage decreases below the battery voltage, the battery takes over and supplies power to the D.C. no-break load. This condition can be caused by a failure of the mains or by fault conditions in the rectifier sets or wiring and switching equipment. Under mains failure conditions the normally stationary set senses the failure, and starts after a preset time. The set runs up to correct operating speed and its output is connected to the essential busbar, which in turn restores power to the rectifier sets. The rectifier set output voltage returns to a level above the battery voltage, and the D.C. no-break load is restored to the rectifier set supply. The rectifier set output also restores the battery to its fully charged condition. The normally stationary set runs and supplies the load for a minimum specified period to prevent frequent changeovers should the mains fail several times within a short period.

With the system shown in Fig. 1, the power supply to the no-break load is maintained, despite failure of the mains supply. Even if the N.S. set fails to start, the N.B. load is supplied from the battery for a minimum of 3 hours. During this time the fault on the N.S. set can be repaired, or alternatively, arrangements can be made for an emergency supply (for example a mobile diesel alternator set).

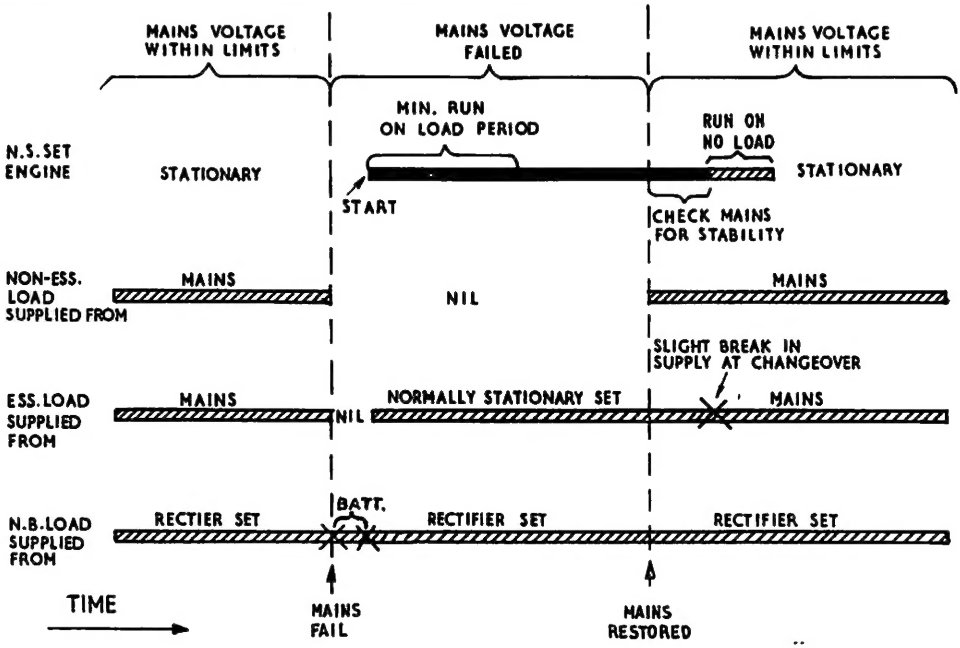


FIG. 2. OVERALL OPERATION.

When the mains supply is restored to normal it is monitored for a period to ensure that stability has been restored. After this period has expired, and the monitoring circuit is satisfied that the mains are stable, a signal is provided to reconnect the mains supply to the essential busbar and to initiate close down of the N.S. set. The mains supply is restored to the essential load, part of which is the rectifier sets supplying the no-break load. The N.S. set continues to run on no load for a period and then closes down. Fig. 2 summarises the overall operation under mains failure conditions and should be studied carefully. Note that a sight break (less than 1 second) occurs in the supply to the essential busbar during the changeover between N.S. supply and mains supply.

2.4 RECTIFIER SET ARRANGEMENTS. Fig. 3 shows a basic diagram of a typical D.C. no-break installation. The overall installation comprises an N.S. set, two rectifier sets and two batteries. The N.S. set provides a standby supply to the essential busbar as described in paragraph 2.3.

Each of the rectifier sets is capable of supplying the full telecom load, and under normal circumstances one set is on duty while the other set acts as a standby. This arrangement allows boost charging of the batteries as required, and has the advantage that a fault condition in a rectifier set does not affect the normal supply to the load. A manually operated switch on each rectifier set determines whether the set is to act as the duty set, or whether the set is to act as the standby set.

Should the output current of the duty set exceed 95% of its rated capacity, the standby set switches on automatically, and shares the load equally with the duty set (referred to as load sharing). The standby set switches off automatically when the output current of the duty set decreases to 40% of its rated value.

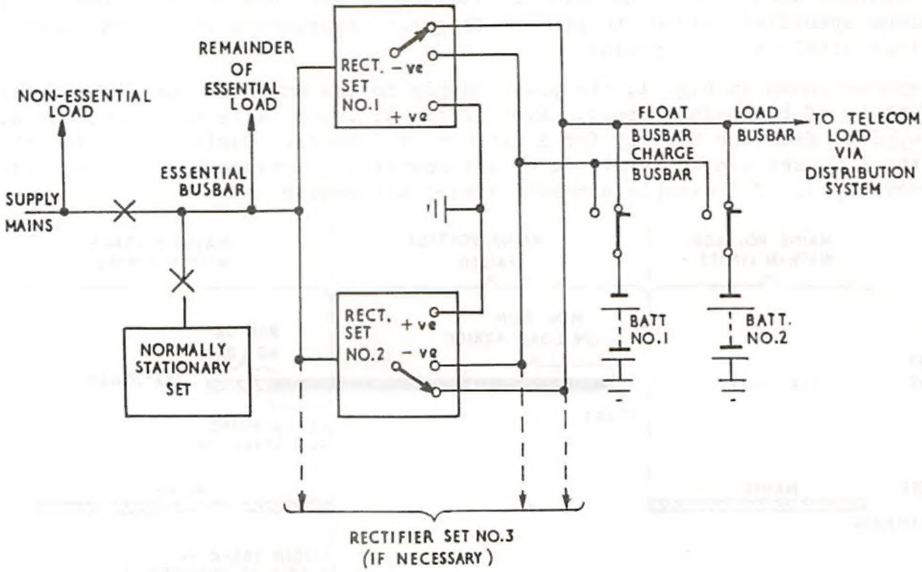


FIG. 3. TYPICAL D.C. NO-BREAK INSTALLATION(MAINS).

In large installations, where the telecom load is beyond the capacity of a single rectifier set, additional rectifier sets are provided, and are arranged for automatic sequential switching. For example, in situations where two rectifier sets are required to supply the full station load, an extra set is provided, making a total of three.

As in the two rectifier set installation, any set can be nominated as the duty set. In this case, however, we have two standby sets; one being nominated as the No. 1 standby the other being nominated as the No. 2 standby. Under these conditions, the duty set supplies the telecom load and battery float current until its output rises to 95% of its rated capacity. At this point, the number 1 standby set switches on automatically and shares the load equally with the duty set. If the station load continues to rise and the output current of either the duty set or No. 1 standby set exceeds 95% of its rated capacity, the No. 2 standby set switches on and load shares with the other two sets.

When the station load decreases, the output of each rectifier set decreases until the output of the No. 1 standby set falls to 40% of its rated capacity. At this point the No. 2 standby set switches off automatically and the remaining two sets share the load equally. The No. 1 standby set switches off when the output of the duty set decreases to 40% of its rated capacity.

Note that large power installations are designed so that, under normal circumstances, there is always a reserve rectifier set. This means that the set selected as the last-in-line standby is only used under abnormal load conditions or when a fault occurs in one of the sets supplying the load.

2.5 BATTERY ARRANGEMENTS.

At mains powered D.C. no-break installations the batteries are operated under what is referred to as a "float" system (as distinct from a cycling system described in Section 5). Under the float system the batteries (or battery in small installations) are connected in parallel with each other and the output of the rectifier sets (or rectifier set), and are maintained in a fully charged condition by setting the output voltage of the rectifier sets so that each cell is maintained at a voltage slightly above its true open circuit voltage. This method of operating the batteries has the following features:

- The full battery capacity is available in the event of failure of the A.C. supply to the essential busbar.
- Energy costs and maintenance costs are kept to a minimum.
- Maximum life is obtained from the battery.

Since the batteries are connected to the load under normal working conditions (Fig. 3) no break occurs in the supply to the load during changeover between the rectifier set supply and the battery supply. The power supply with the highest voltage supplies current to the no-break load. A changeover occurs each time the supply to the essential busbar fails and after the supply to the essential busbar is restored.

Research has shown that maximum life is obtained from a lead-acid battery when it is floated at precisely 2.17 volts per cell. The maximum allowable variation for telecom power installations has been set at ±0.03 volts per cell. This means that the limits for a 12 cell installation are set at 25.5 V and 26.5 V, and for a 24 cell installation at 51.3 V and 52.8 V. Most telecom installations are provided with alarm facilities to warn of abnormal float voltage conditions which persist for more than three to four minutes.

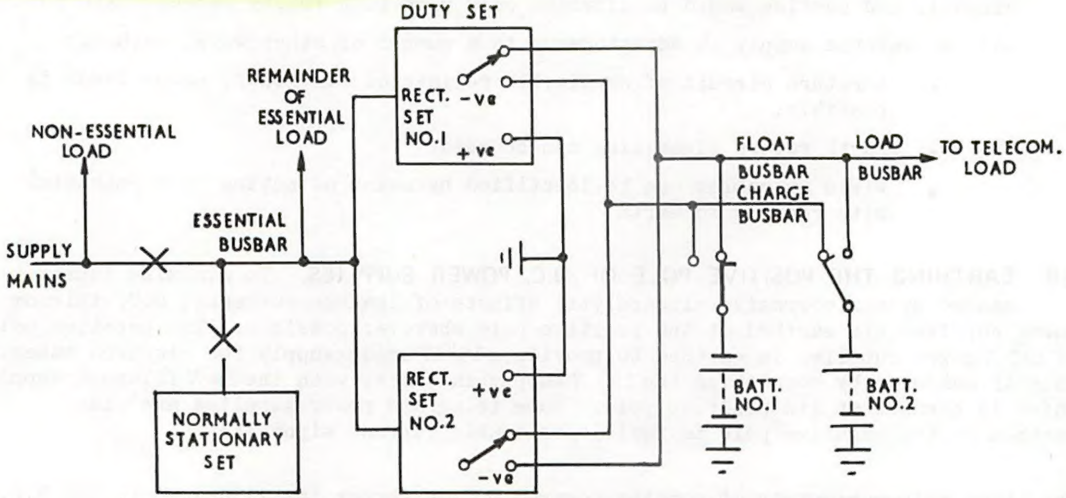


FIG. 4. CHARGING A BATTERY IN A MULTIPLE BATTERY INSTALLATION.

If for some reason one battery in a multiple battery installation needs charging during its lifetime, it is removed from duty and connected to the charge busbar. The off-duty rectifier set is used to charge the battery as required by operating its control switch to the "Boost Charge" position and connecting its output to the charge busbar (see Fig. 4).

In the case of single battery installations it is necessary to use a higher than normal float voltage when a special charge is required. It is important that the voltage limits of the associated telecom equipment are not exceeded when carrying out this procedure.

2.6 VOLTAGES. Most modern D.C. power installations provide a voltage of either 24 V negative or 48 V negative. Batteries associated with these installations are made up of 12 cells and 24 cells respectively.

D.C. no-break power supplies associated with transmission equipment using electron tubes usually have two separate power supplies; 24 V negative and 130 V positive. The 130 V batteries are made up of 63 cells.

Other D.C. voltages are used to supply telecom equipment but the majority of installations are covered in the above categories.

2.7 EARTHING OF D.C. POWER SUPPLIES. D.C. power supplies always have one pole connected to earth for the following reasons:

(a) To simplify fusing and switching circuits; only the conductor above earth potential is fused and switched.

(b) To reduce crosstalk and noise; these arise from currents via leakage and capacity unbalance paths and are difficult to eliminate if lines and equipment are allowed to assume an indeterminate potential with respect to earth.

(c) To ensure prompt indication of insulation faults to earth and to assist in locating them. When the insulation to earth of any part of a system fails, a circuit is completed via the power supply and the fault is indicated promptly by the operation of a fuse, a relay, or other supervisory device. Without the earthed power supply the fault circuit could only be completed via another fault circuit, and service would be affected only when both faulty circuits are in use.

(d) An earthed supply is advantageous in a number of other ways, such as:

- A return circuit of negligible resistance for P.B.X. power leads is possible.
- Earth return signalling can be used.
- Wires in cables can be identified by means of noting their potential with respect to earth.

2.8 EARTHING THE POSITIVE POLE OF D.C. POWER SUPPLIES. To minimise faults caused by the corrosive electrolytic effects of leakage currents, D.C. telecom power supplies are earthed at the positive pole wherever possible. The negative pole of 130 V power supplies is earthed to provide a 154 V anode supply for electron tubes. This is achieved by connecting the 130 V supply in series with the 24 V filament supply which is earthed at its positive pole. Some telegraph power supplies are also earthed at the negative pole to facilitate double current signalling.

The three main components of a mains powered D.C. no-break installation are the N.S. set, the rectifier sets, and the batteries. The following two sections of this paper explain the principles of N.S. sets and rectifier sets. Batteries are covered in the paper primary and secondary cells and E.Is. POWER PLANT Batteries I 0010 and M 5020.

3. NORMALLY STATIONARY SETS

3.1 FACILITIES. Many different types of N.S. plant are used in the Department. When new plant is purchased, the facilities specified are modified to suit the requirements of modern telecom equipment. The facilities provided by a typical set are:

- Maintenance of an A.C. supply to the essential load, either from the mains or the diesel-alternator, with a break in supply during changeover.
- Automatic engine start and changeover from the mains supply to standby supply when the mains voltage varies outside preset limits.
- Adjustable delay of engine start, and up to three separate attempts to start the diesel engine.
- Automatic change back to normal,after an adjustable delay, when the mains supply is restored. The engine is stopped after an adjustable run on no load period.
- Automatic shut down of the plant and extension of an alarm under the following conditions:
  - Alternator overload.
  - Alternator overvoltage.
  - Low oil pressure.
  - Engine overheated.
  - Engine overspeed.
  - Failure to start.
  - Fuel empty.
- Extension of an alarm under the following conditions:
  - Fuel low.
  - Battery charger failure.
- During plant failure conditions, immediate restoration of the mains to the load as soon as the mains voltage returns to normal.
- Automatic start of the diesel engine and changeover from mains to standby supply, in response to a signal from an A.C. no-break set.
- Manual switching to isolate the set and connect the essential load direct to the mains supply.
- Manual switching to connect the essential busbar direct to the mains supply without isolating the set.
- Manual controls to start and stop the plant at the engine and control cubicle.
- Provision for charging the control battery.
- Visual indication of the various modes of operation and alarms.
- Metering of output voltage, current, and frequency.

3.2 GENERAL DESCRIPTION. A single line diagram of a typical N.S. set is shown in Fig. 5. The supply mains are connected via switch SWB, mains contactor CRM, and a second set of SWB contacts to the essential busbar. The mains voltage is monitored by a sensing circuit for both low and high voltage conditions.

MAINS FAILURE. When the voltage varies from its nominal value by a predetermined margin, a signal is applied to the control circuit to start the engine. On complete failure of the mains, CRM releases immediately and disconnects the supply from the essential busbar. The mains contactor CRM and plant contactor CRP are mechanically and electrically interlocked to prevent both being in the operated position at the same time.

ENGINE STARTING. After an adjustable delay period, the control circuit applies starting conditions to the diesel engine. The starter motor starts the engine and is disconnected when the engine reaches a speed of 350 R.P.M. Up to three separate attempts, each lasting ten seconds, are made to start the engine.

CONNECTING THE ALTERNATOR. A voltage sensitive relay in the sensing circuit operates when the output voltage of the alternator reaches 200 V. Its contacts open circuit the mains contactor and prepares a circuit for the plant contactor. With CRM released and the alternator output above 200 V, CRP operates to connect the output to the essential busbar. The CRE contactor is also operated to allow the set to supply selected equipment in the non-essential load.

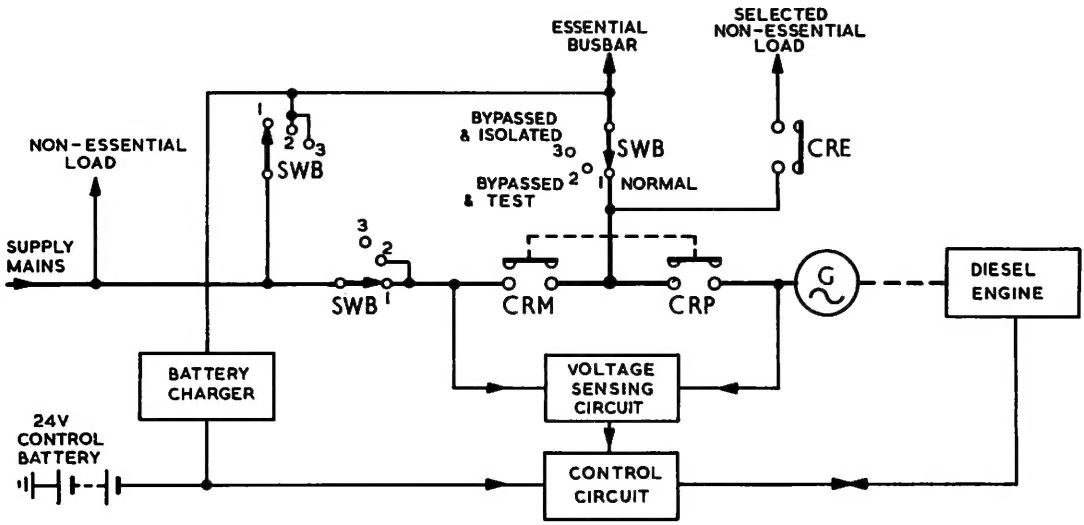


FIG. 5. SINGLE LINE DIAGRAM OF A TYPICAL N.S. SET.

MAINS RESTORATION. When the mains voltage returns to normal, sensing relays signal the control circuit to prepare for reconnection of the mains supply. An adjustable timer ensures that the set supplies the load for a minimum period to allow the engine to reach operating temperature, and also prevent frequent changeover of supplies should the mains fail a number of times in a short period. After the delay period is completed, CRP is released and one of its contacts closes a circuit for CRM which reoperates and reconnects the mains to the essential load. The CRE contactor is also released by a contact of the adjustable timer.

ENGINE RUN-ON NO LOAD. While on load, the engine is brought up to operating temperature to dispose of unburnt gases which dilute the crankcase oil. It is now allowed to run on no load for a period to reduce its temperature, and to ensure that the transfer back to the mains has been satisfactorily completed. If the engine is stopped immediately the mains are reconnected, the temperature alarm may operate and prevent further starting in the event of another mains failure (particularly on water-cooled engines). Should the mains fail during the run-on no load period, the supply to the essential load is changed over immediately. After the run-on no load period is completed the fuel supply is cut off to stop the engine.

BYPASS FACILITIES are provided to allow maintenance to be carried out on the plant under safe working conditions. When SWB is operated to "Bypassed & Test", the mains are connected directly to the essential busbar without disconnecting the input to the set. In the "Bypassed and Isolated" position the input is disconnected and the N.S. set bypassed.

BATTERY CHARGING FACILITIES are provided to maintain the control battery in a fully charged condition.

3.3 EQUIPMENT LAYOUT. The set is usually placed in a separate room with special provision for noise attenuation and air circulation. A typical installation is shown in Fig. 6 and consists of:

- Alternator.
- Diesel engine.
- Control cubicle.
- Control battery.
- Battery charger.

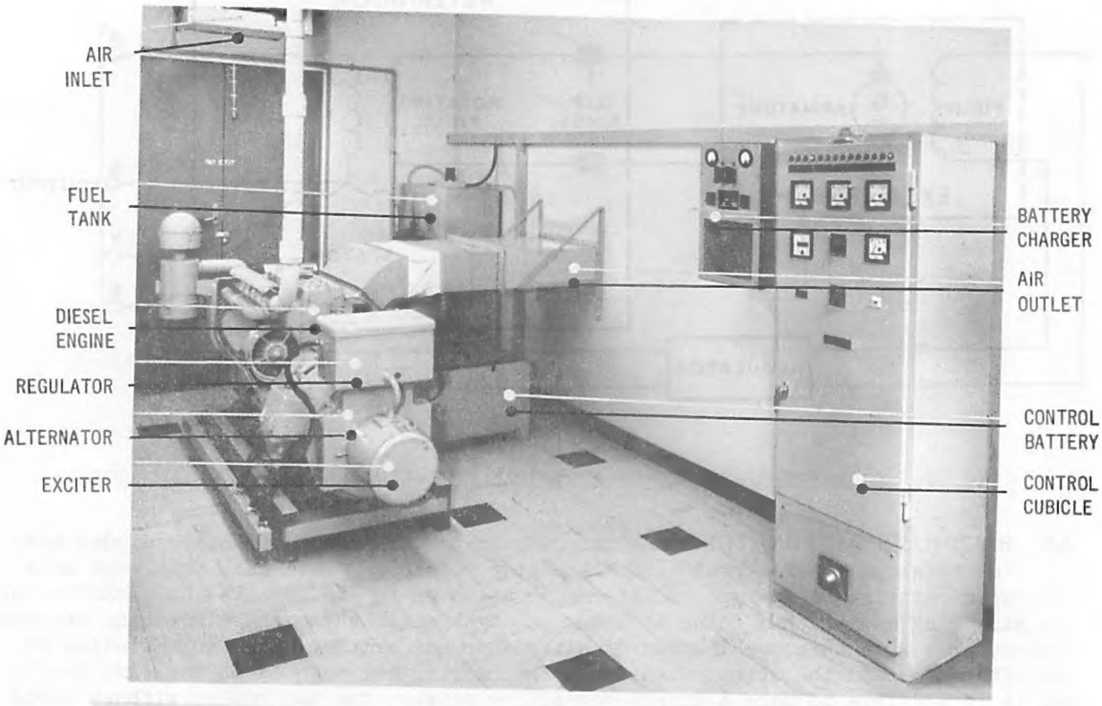


FIG. 6. TYPICAL N.S. INSTALLATION.

3.4 ALTERNATORS. The three basic types of alternator are rotating field, rotating armature and the inductor alternator. The rotating field type is used in most N.S. installations to minimise connecting and insulating problems associated with the output windings. Some small stations use the rotating armature type of machine, but the low output power of the inductor alternator makes it unsuitable for use in standby plant. Alternators used in N.S. plant usually provide a regulated three phase output, and the two main types in use are:

- Slip-ring and brush alternators.
- Brushless alternators.

3.5 SLIP–RING AND BRUSH ALTERNATORS. A typical slip-ring and brush alternator is shown in Fig. 7. It is possible to use either the rotating field or rotating armature type of machine; Fig. 7 shows the rotating field type. The D.C. required for excitation is supplied from a small D.C. generator which is mounted on the rotor shaft or belt driven from it. The output of the machine is connected directly from the stator windings. Direct current from the exciter generator is connected via slip rings to the rotating field, and determines the output voltage of the alternator by controlling the field strength.

To obtain a constant output voltage under varying load conditions, a sample of the alternator output is connected via a regulator to the field winding of the exciter generator. Any change in output voltage is sensed by the regulator which varies the field current of the exciter. This varies the magnitude of the D.C. in the alternator field winding which in turn corrects the output voltage. Both mechanical and static regulators are used on slip-ring and brush alternators.

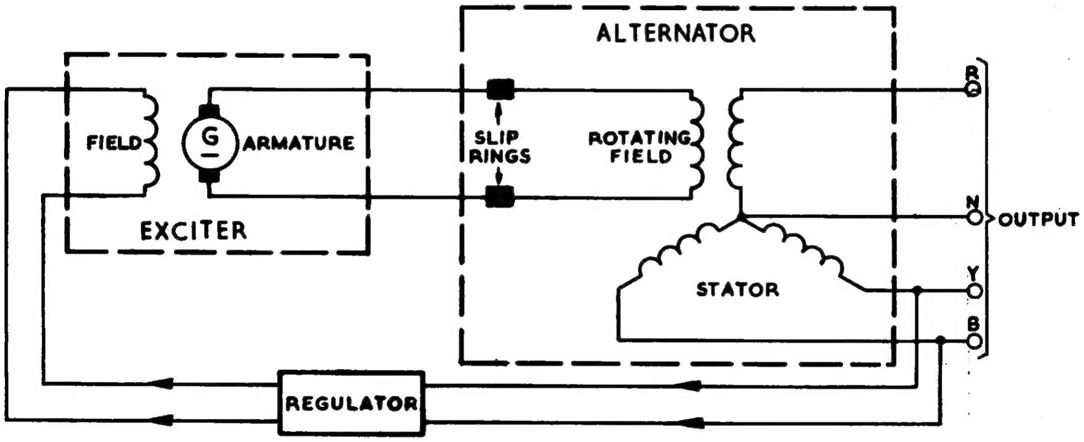


FIG. 7. SIMPLIFIED CIRCUIT OF A TYPICAL SLIP-RING AND BRUSH ALTERNATOR.

3.6 BRUSHLESS ALTERNATOR. The introduction of silicon solid state diodes made the development of a brushless alternator possible. This machine always uses the basic rotating field type of alternator as shown in Fig. 8. The D.C. exciter of the slip-ring and brush machine is replaced by a small three phase rotating armature alternator. With this combination of alternator and exciter, the field winding of the alternator and the output winding of the exciter are mounted on the same shaft, and it is possible to make a direct connection between the two rotors without using slip-rings and brushes. As the field current for the alternator must be D.C., the A.C. output of the exciter alternator is rectified by a three phase full wave bridge circuit. The six diodes used for this purpose are mounted on a plate secured to the shaft. An automatic voltage regulator maintains the output voltage of the machine at a constant value by controlling the field current of the exciter.

The brushless alternator has advantages over the slip-ring and brush type of machine in that commutators, brushes, and slip rings are eliminated, making the machine more reliable. Also, the initial cost and maintenance are reduced. Fig. 9 shows the basic construction of a typical brushless alternator.

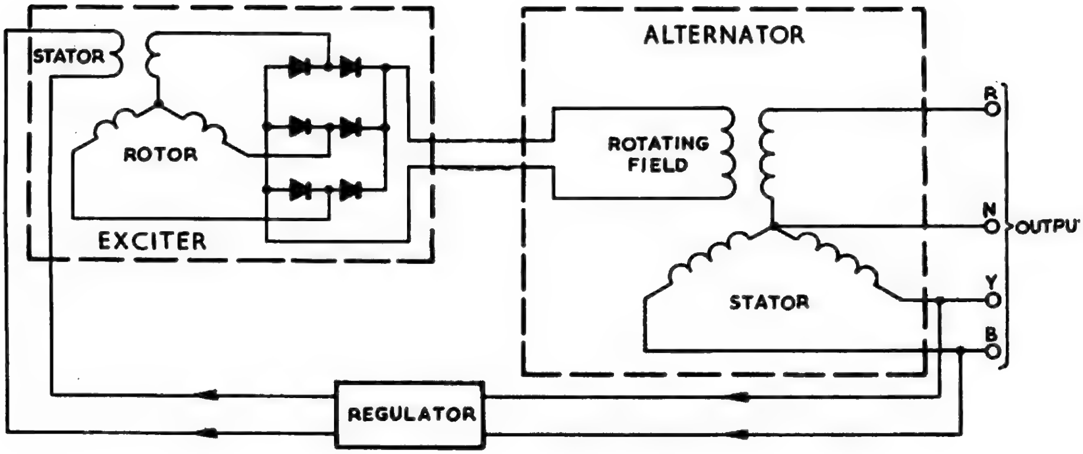


FIG. 8. SIMPLIFIED CIRCUIT OF A TYPICAL BRUSHLESS ALTERNATOR.

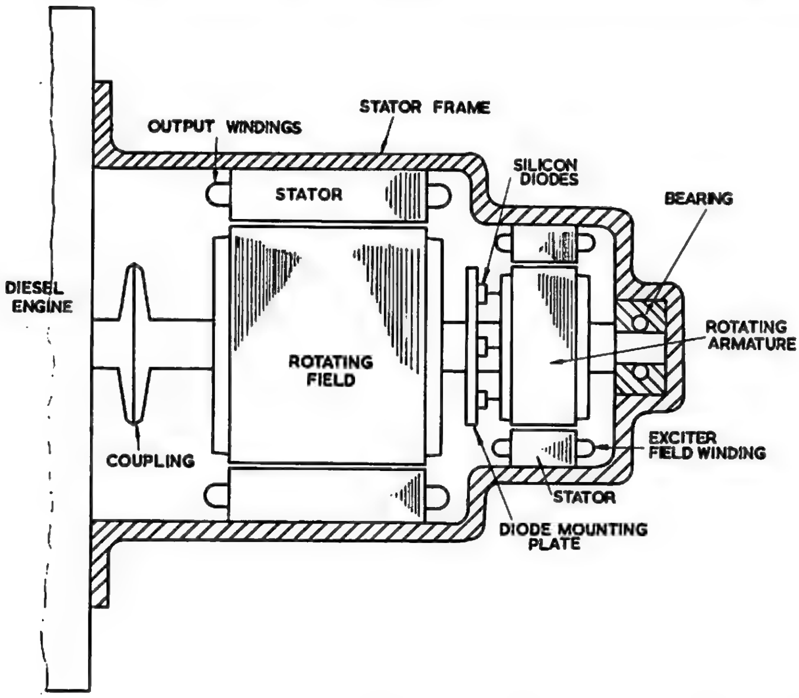


FIG. 9. BASIC CONSTRUCTION OF A TYPICAL BRUSHLESS ALTERNATOR.

3.7 REGULATORS. Two basic types of regulator are used on alternators; mechanical regulators and static regulators. The Brown Boveri regulator is an example of the mechanical type. Although several different types of static regulators are in use, the basic principle of operation remains the same and is shown in Fig. 10. Note the similarities between the principles of operation of regulators used on alternators and regulators used on rectifier sets (Figs. 10 and 21.)

A portion of the alternator output is connected via a rectifier and control device to the field winding of the exciter. A sample of the alternator output is compared with a reference voltage by the comparator. The output of the comparator is amplified and applied to the control device. When the output voltage varies from its nominal value, the comparator senses the change and a signal is given to the control device to increase or decrease the current in the field winding of the exciter. We saw from Fig. 7, that we could control the alternator output voltage by varying the current in the exciter field winding. The control device is usually a transductor, a transistor, or a thyristor.

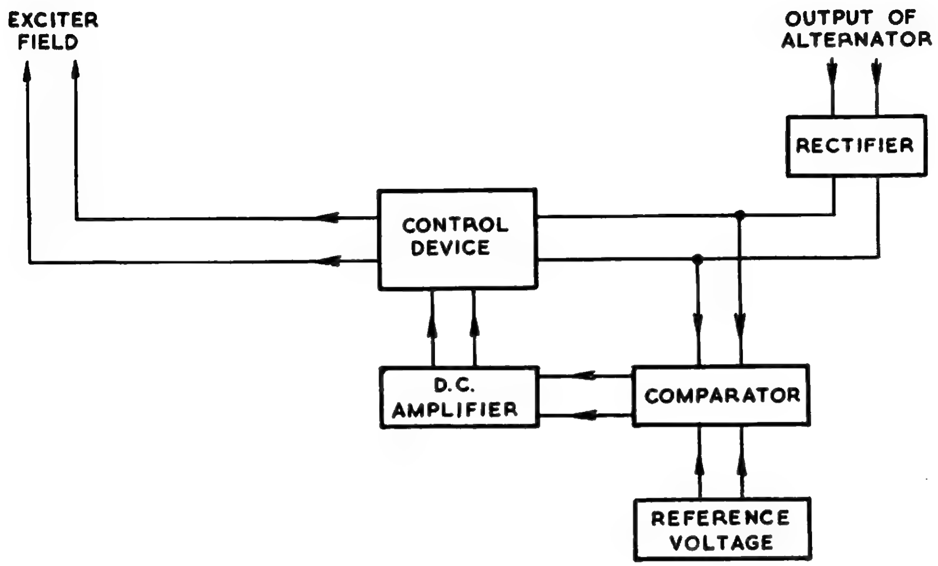
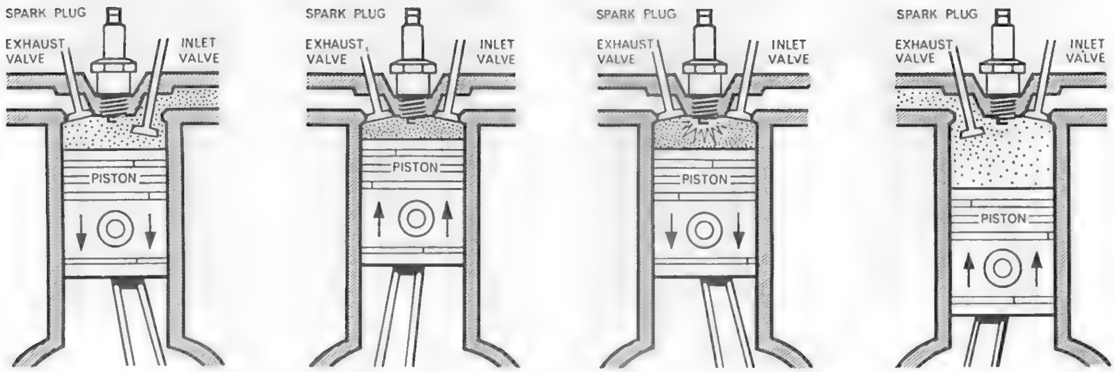


FIG. 10. TYPICAL STATIC REGULATOR.

3.8 ENGINES used in N.S. plant are required to provide reliable service on intermittent duty. Although some sets still use petrol engines, the diesel engine is preferred because of its lower fire risk, greater fuel economy, and reliable starting.

(a) FOUR STROKE PETROL ENGINE. The operating principle of the four stroke petrol engine is shown in Fig. 11. It is called a "four stroke" engine because four strokes of the piston are required to complete the working cycle.

- INLET STROKE. The piston travels down, the inlet valve opens, and a combustible mixture of petrol and air enters the cylinder through the inlet valve port. The exhaust valve remains closed during this stroke.
- COMPRESSION STROKE. The piston moves up while both valves are closed and the petrol and air mixture is compressed between the piston and cylinder head.
- POWER STROKE. When the piston almost reaches the end of the compression stroke, the petrol and air mixture is ignited by a spark from the spark plug. Combustion causes the mixture to expand rapidly and force the piston down. The valves are still closed during this stroke.
- EXHAUST STROKE. The piston moves upward, the exhaust valve opens, and the burnt gases are forced out through the exhaust port.



(a) Inlet Stroke. (b) Compression Stroke. (c) Power Stroke. (d) Exhaust Stroke.

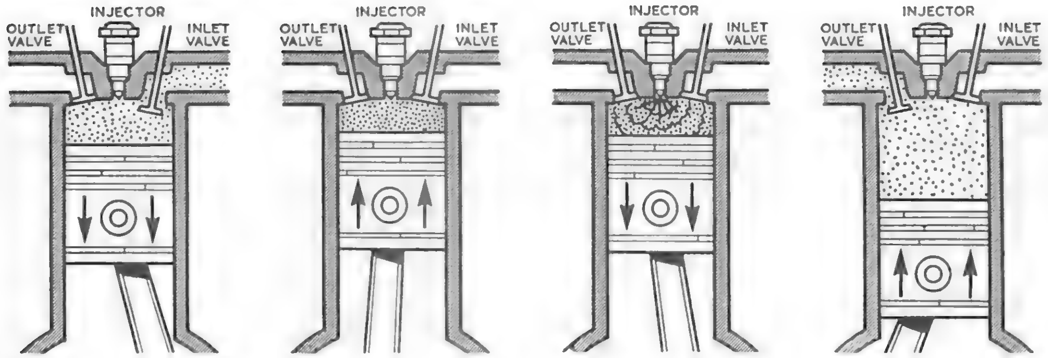
FIG. 11. CYCLE OF OPERATION OF A FOUR STROKE PETROL ENGINE.

(b) FOUR STROKE DIESEL ENGINE. The operating principle of the four stroke diesel engine is shown in Fig. 12. The basic difference between petrol and diesel engines is the method by which the fuel is ignited in the cylinder. In the petrol engine a mixture of fuel and air is drawn into the cylinder and ignited by the spark plug. In the diesel engine, only air is drawn into the cylinder by the movement of the piston. During compression the air heats, and at the end of the compression stroke combustion is initiated by a fine spray of diesel fuel which is pumped (injected) at high pressure into the cylinder. This eliminates the need for an electrical ignition system.

The complete operating cycle consists of the following four strokes:

- INLET STROKE. The piston travels down, the inlet valve opens, and air is drawn into the cylinder through the inlet valve port.
- COMPRESSION STROKE. The piston moves up while both valves are closed and the air is compressed between the piston and the cylinder head and heats to about 700°C.
- POWER STROKE. Just before the piston completes the compression stroke, fuel oil is injected into the cylinder and starts to burn due to the high temperature. Expansion of the gases formed forces the piston down the cylinder. Both valves are closed during this stroke.
- EXHAUST STROKE. The exhaust valve opens, and the rising piston forces the burnt gases out of the cylinder via the exhaust port. At the end of this stroke the exhaust valve closes and the inlet starts to open again for the next cycle.

Air cooled diesels are preferred because of their fast warm up time and lower maintenance costs; they are used on most sets up to 60 kVA. Water cooled engines are used on some small sets and most plants above 60 kVA. Although engines are usually started by electric starter motors, a few large diesels use compressed air starting. An engine mounted control panel provides facilities for the manual starting and stopping of the set. The fuel tank is usually mounted on a stand in the same room as the plant. The three standard sizes of fuel tanks are 50, 100 and 150 gallons.



(a) Inlet Stroke. (b) Compression Stroke. (c) Power Stroke. (d) Exhaust Stroke.

FIG. 12. CYCLE OF OPERATION OF A FOUR STROKE DIESEL ENGINE.

3.9 CONTROL CUBICLE. This cubicle provides mounting space for control gear, sensing circuits and supervisory and alarm equipment associated with the set. Many different types of cubicles are in use at telecom stations, and equipment layout on new sets is altered as facilities are modified to suit new telecom plant. Fig. 13 shows a typical face layout of an island type control cubicle.

Switch SWB is an isolate and bypass switch. It allows the set to be bypassed for testing purposes, or bypassed and isolated for maintenance.

Switching facilities are provided by SWA to connect the frequency meter and voltmeter between any phase and neutral of the mains supply or plant output. An ammeter for each phase is connected in the supply to the essential busbar.

Switch SWC is used as an on-off and test switch for the set. The plant is on when it is operated to the "Normal" position. When operated to the "Test no Changeover" position, the engine is started but there is no changeover of the supply to the essential busbar. The "Test and Changeover" position open circuits one phase of the mains supply to the sensing circuit, and initiates a normal changeover of supply.

The hour meter is connected across the output of the alternator and records the total running time of the engine.

The total number of engine starts is recorded on the start count meter.

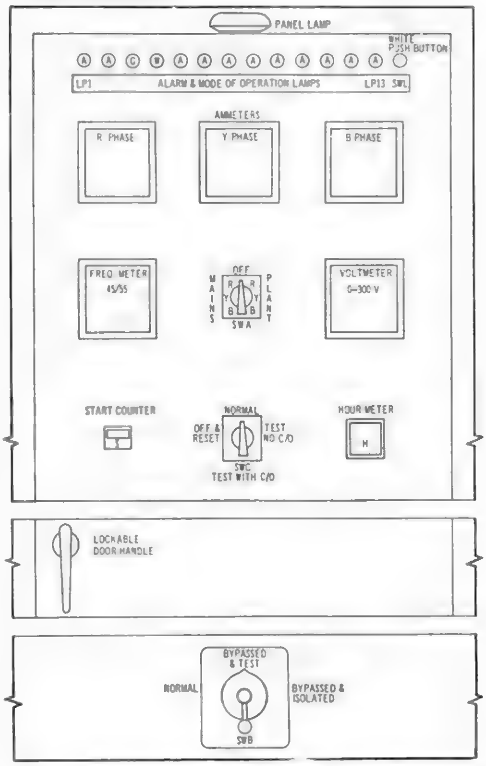


FIG. 13. TYPICAL CONTROL CUBICLE FACE LAYOUT.

Thirteen lamps mounted at the top of the panel provide a visual indication of the various modes of operation and alarm conditions associated with the plant.

Push button SWL provides a continuity test on lamps.

3.10 CONTROL BATTERY. This battery provides power for the operation of the control equipment and engine starter motor. The battery must be able to withstand the large current drain during engine starting, and it must be located as close as possible to the engine to avoid excessive voltage drop on the connecting leads to the starter motor. The two main types of battery used are lead-acid, and nickel-cadmium.

In the case of lead-acid batteries a heavy duty automotive type is used to ensure reliable service, and as reliability is of the utmost importance, the batteries are replaced every two years.

Many N.S. sets are now using nickel cadmium batteries. The main advantages of these batteries are:

- Longer life.
- Ability to withstand high rates of charge and discharge.
- Less maintenance.

The internal resistance of nickel cadmium batteries is extremely low and each cell provides a voltage of approximately 1.2 V. High initial cost and limited maximum operating temperature are their main disadvantages. Nickel cadmium cells use an alkaline electrolyte, and acid must not be added under any circumstances.

3.11 BATTERY CHARGER. A constant potential rectifier maintains the control battery in a fully charged condition. The rectifier is supplied from the essential busbar and has facilities for "trickle" and "boost" charging. Although some chargers are mounted in the control cubicle, the usual practice is to use the wall mounted type as shown in Fig. 6.

4. RECTIFIER SETS

4.1 FACILITIES Rectifier sets used in telecom power installations range in size from sets with outputs of less than one amp at 24 V to sets with outputs of 800 amps at 50 V. In mains powered D.C. no-break installations with two standby supplies, at least two rectifier sets are provided and are mounted in a suite together with a distribution cubicle. The facilities offered by a typical suite are:

- Conversion of an A.C. power supply to a smoothed D.C. power supply.
- Maintenance of D.C. output voltage within specified limits despite changes in input voltage and frequency, output current, and temperature.
- Automatic limiting of the output current to a safe level.
- Automatic load sharing between sets supplying a common load.
- Manual control over the mode of operation of the rectifier sets. The four modes of operation are:
  - Manual. In this mode the output voltage of the set is controlled manually and the automatic voltage regulating circuit is disabled.
  - Float-Duty. In this mode the output voltage is preset at 2.17 V/cell and is under the control of the automatic voltage regulating circuit. The set is permanently energised and supplies the load.

Float-Standby. In this mode the output voltage is set and controlled as for float-duty, but the rectifier set is energised only when the load exceeds the output of the duty set, or when an alarm condition closes down the duty set.

Auto-boost. In this mode the output voltage is under the control of an automatic voltage regulator, and the nominal output voltage is set by means of a manual control. The mode is used for boost charging a battery via the charge busbar.

- Automatic sequential switching of rectifier sets (see para. 2.4).
- Manual switching to permit switching of the output of the rectifier set and batteries as required.
- Visual indication and extension of alarm conditions. For example:
  - Overload tripped.
  - Filter capacitor failure.
  - Fuse operated.
  - Float voltage low.
  - Float voltage high.
  - Load voltage out of limits.
- Metering of output voltage and current.

It is important to realise that the facilities offered by rectifier sets vary widely, and that the above list relates only to a typical set. Reference should be made to the relevant manufacturer's handbook for facilities offered by a particular set.

4.2 RECTIFIER SET SUB-CIRCUITS. The principle of operation of a rectifier set is best understood by dividing its circuit into a number of smaller functional sub-circuits. The main sub-circuits to be found in most rectifier sets are the:

- Transformer circuit.
- Rectifier circuit.
- Filter circuit.
- Voltage regulating circuit.
- Current limiting circuit.
- Switchgear circuit.
- Measuring instrument circuit.

4.3 TRANSFORMER CIRCUIT. Most D.C. powered telecom equipment requires a voltage of 24 V or 50 V at the entry point to the rack or unit. For this reason it is necessary to use a transformer to step down the mains voltage of 240 V (single phase) or 415 V (three phase) to the level required. The transformer used for this purpose is connected between the input to the rectifier set and the rectifying circuit as in the two typical circuits shown in Fig. 14. Tappings are usually provided on the primaries of the transformers to facilitate adjustments for available line voltages. Some older transformers have tapped secondaries to permit adjustments required because of ageing of rectifier elements (copper oxide and selenium types).

Large rectifier sets sometimes employ a six phase arrangement to improve the overall performance of the set. Fig. 15 shows a typical configuration using two separate transformers. Other sets use one transformer with two separate secondaries. In Fig. 15, TR1 is connected in star-delta configuration, and TR2 is connected in delta-delta. The secondary voltages of the transformers are displaced in phase by 30° because of the different configurations, and therefore produce a 12 pulse output when the two supplies are rectified and connected in parallel. This increases the ripple frequency at the D.C. output and consequently reduces the size of filter components.

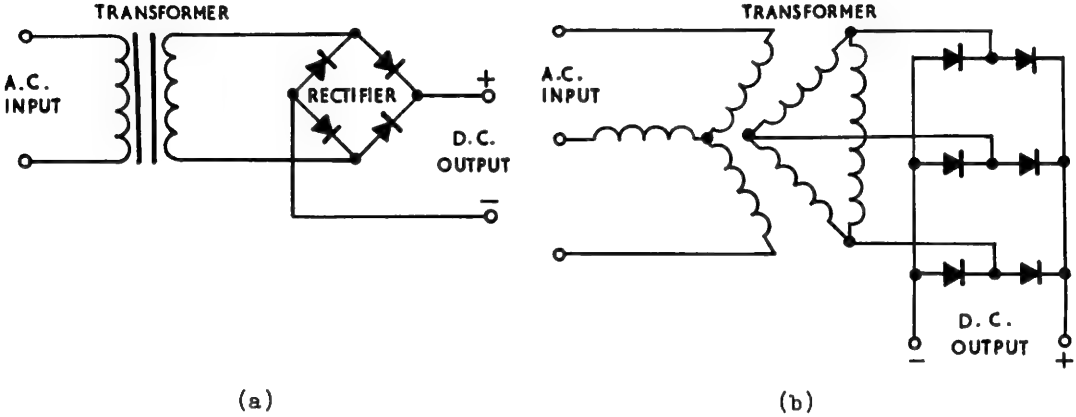


FIG. 14. BASIC TRANSFORMER CONNECTIONS.

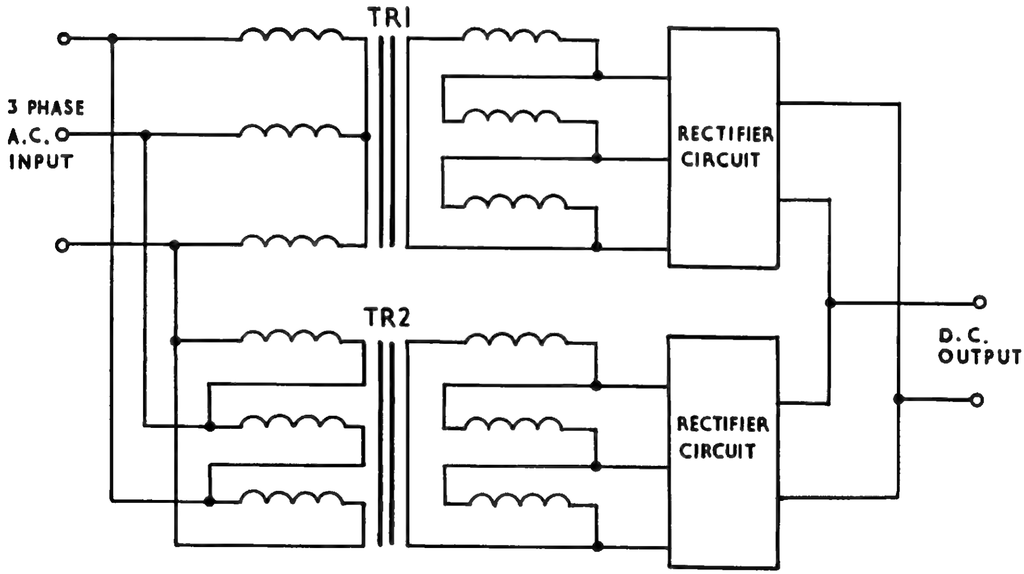


FIG. 15. TYPICAL SIX PHASE TRANSFORMER CONNECTION.

4.4 RECTIFIER CIRCUIT. Most rectifier sets used in telecom power installations use either a single phase full-wave rectifier or a three phase full wave rectifier. Generally, the single phase bridge is used in sets with outputs up to 3 kW, and the three phase bridge is used in sets above this size.

Silicon diodes are used as the rectifying device in the majority of new sets being purchased at the time of writing, and are also being used to replace existing copper oxide and selenium rectifier stacks. Some new sets being purchased use thyristors instead of the diodes, because they have the advantage that they combine the rectifying function with a control function (see para. 4.10). Fig. 16 shows various rectifier configurations, and comparisons between output waveforms, voltages, and ripple frequencies.

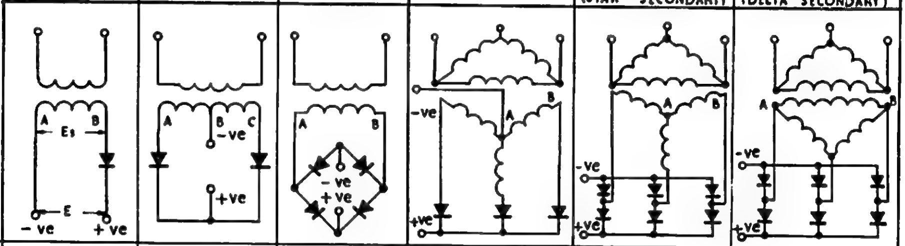
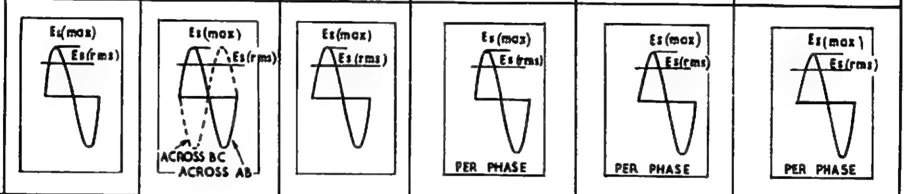
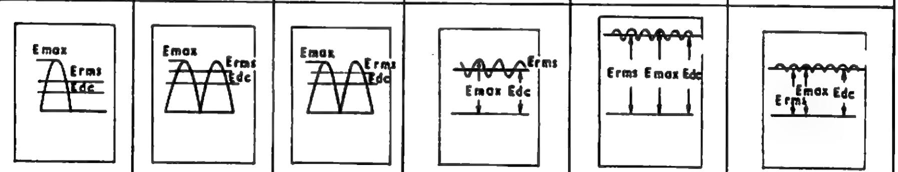
	SINGLE PHASE			THREE PHASE.		
	HALF-WAVE	PUSH-PULL FULL-WAVE	FULL-WAVE BRIDGE	HALF-WAVE	FULL-WAVE BRIDGE (STAR SECONDARY)	FULL-WAVE BRIDGE (DELTA SECONDARY)
TYPE OF RECTIFIER CIRCUIT						
SECONDARY INPUT VOLTAGE(E_s) (50 Hz)						
OUTPUT VOLTAGE (E)	 Emax = Es(max)	Emax = Es (max)	Emax = Es(max)	Emax = Es (max)	Emax = √3 Es (max)	Emax = Es(max)
RIPPLE FREQUENCY	50 Hz	100 Hz	100 Hz	150 Hz	300 Hz	300 Hz
AVERAGE CURRENT PER RECTIFIER ARM IN TERMS OF OUTPUT CURRENT (Idc)	Idc	0·5 Idc	0·5Idc	0·33 Idc	0·33Idc	0·33 Idc
AVERAGE OUTPUT VOLTAGE Edc IN TERMS OF Emax	0·318 Emax	0·636 Emax	0·636 Emax	0·826 Emax	0·955 Emax	0·955 Emax
PEAK OUTPUT VOLTAGE (E max) IN TERMS OF Edc.	3·14 Edc	1·57 Edc	1·57 Edc	1·21 Edc	1·05 Edc	1·05 Edc

FIG. 16. RECTIFIER CONFIGURATIONS.

4.5 **FILTER CIRCUIT.** Since most telecom equipment requires a power supply with a very low "noise" level, filter circuits are provided to "smooth" the outputs of the rectifier circuits described in the previous paragraph. Fig. 16 shows that the most difficult output to smooth is the single phase half wave circuit, because of its low ripple frequency and high ripple amplitude. The three phase full wave bridge circuits are easier to filter because of the increased frequency and decreased amplitude of the ripple. Fig. 17 shows that the filter is connected between the rectifier circuit and the D.C. output terminals of the rectifier set.

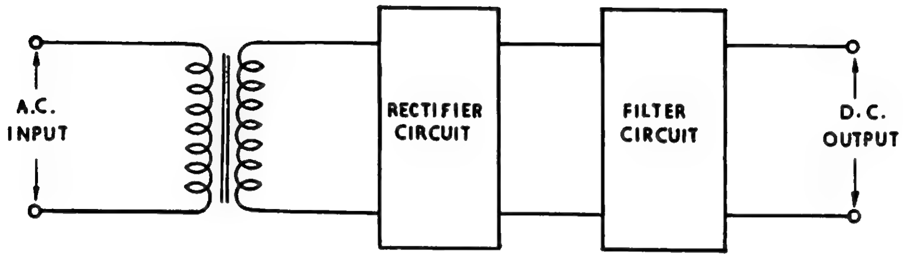
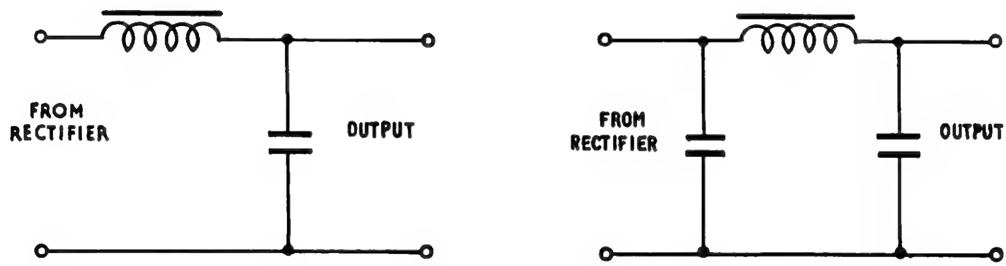


FIG. 17. CONNECTION OF THE FILTER CIRCUIT.

The output from any rectifier circuit is varying D.C., as shown in Fig. 16. Any varying D.C. may be regarded as comprising two components; a steady D.C. component with a superimposed A.C. component. The function of the filter circuit is to smooth the A.C. component so that a steady D.C. appears at the output of the rectifier set.



(a) Choke Input. (b) Capacitor Input.

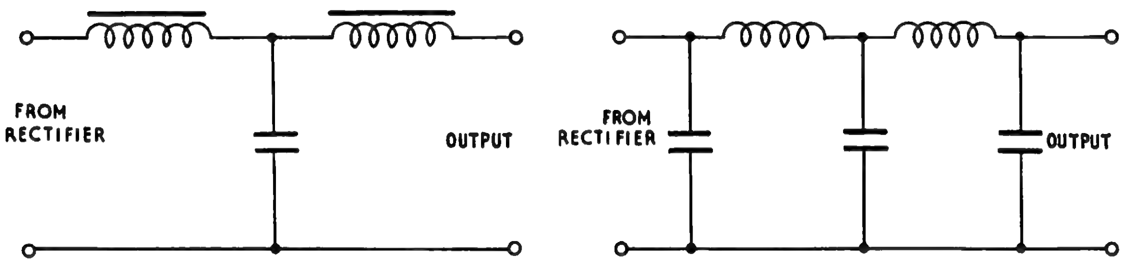
FIG. 18. BASIC FILTER CIRCUITS.

Most rectifier set filters comprise a series inductor and a shunt capacitor, although some low power circuits employ a series resistor instead of the series inductor. The two basic circuits most frequently used in rectifier sets are shown in Fig. 18; they are known as choke input filters and capacitor input filters. Both circuits are simple low pass filters with a cut off frequency lower than the associated ripple frequency.

4.6 CHOKE INPUT FILTERS (Fig. 18a). Choke input filters are used in high current circuits, and low current circuits requiring good voltage regulation (minimum voltage variation over the load range). The circuit is designed so that, at the ripple frequency, the capacitor offers low impedance in comparison to the load impedance. The inductor is chosen to offer high impedance at the ripple frequency, consistent with the requirement that the power loss due to series resistance must be kept to a minimum.

Most of the current due to the ripple voltage at the output of the rectifier circuit flows via the capacitor because of its low impedance. This ensures that the ripple voltage appears across the series inductor rather than across the load.

A smoothing filter may have more than one stage, depending on the degree of smoothing required. Fig. 19a shows a two stage choke input filter suitable for use in a rectifier set used to supply a load and float a secondary battery. Note that the second capacitor is not used because its function is performed by the low impedance battery connected in parallel with the output.



(a) Two Stage Choke Input Filter. (b) Two stage capacitor input filter.

FIG. 19. TWO STAGE FILTERS.

4.7 CAPACITOR INPUT FILTERS (Fig. 18b). The capacitor input filter is similar to the choke input filter, except for the addition of a capacitor across the input. The input capacitor improves the smoothing action by eliminating some of the A.C. component before it is applied to the choke and second capacitor. Because it is connected directly across the output of the rectifier it charges to the peak output voltage of the rectifier circuit, and by acting as a reservoir it tends to maintain this peak voltage to the load via the remaining section of the filter. This effect is pronounced at light loads and is the reason why rectifier circuits associated with capacitor input filters provide a higher output voltage than an equivalent circuit using a choke input filter. As the current drawn by the load increases, the input capacitor discharges to a lower voltage between the peaks of the rectifier circuit output, and the average voltage supplied to the load decreases, resulting in poor output voltage regulation.

This type of filter provides a high degree of filtering, but has the disadvantage of poor output voltage regulation. For this reason, it is generally limited to situations where the load current remains steady. It is also limited to rectifier circuits with comparatively small output currents because of the high peak charging currents required by the input capacitor. Fig. 19b shows a two stage capacitor input filter suitable for a rectifier set not associated with a secondary battery.

4.8 VOLTAGE REGULATING CIRCUIT. One of the requirements of most telecom power supplies is that the output voltage must be maintained within specified limits. This is particularly so when rectifier sets are used to float secondary batteries.

The two main causes of changes in the output voltage of rectifier sets are input voltage changes and the internal resistance offered by devices such as transformers, diodes and filter components. In sets without voltage regulating equipment a decrease in input voltage causes a decrease in output voltage. An increase in load current produces an increase in the voltage dropped across the internal resistance of the set, with a consequent lowering of the terminal voltage. Conversely, an increase in input voltage or a decrease in load current causes the terminal voltage to rise.

Other factors which cause changes in output voltage are temperature and input frequency variations.

The output voltage requirements of rectifier sets are specified by stating the maximum allowable voltage variation for specified load, input voltage, and temperature ranges (a frequency range is also stated in some cases). For example, the D.C. output voltage shall be regulated (controlled) to give a maximum variation of 1 volt from 100% rated output current to 4% rated output current, allowing for input voltage changes of from -17% to +10% of the nominal voltage, and ambient temperatures ranging up to 43°C. To meet this type of specification it is necessary to provide rectifier sets with automatic voltage regulating equipment. A rectifier set is said to be "well regulated" if only a small change in output voltage occurs under varying input, load, and temperature conditions.

In most rectifier sets the voltage regulating equipment maintains the output voltage within specified limits by means of a control device inserted between the input terminals and the filter. The control device regulates the output voltage by varying the voltage dropped across its terminals. For example, when the input voltage rises, the output voltage is maintained within limits by adjusting the control device so that the extra voltage appears across its terminals. Similarly, a decrease in load causes more voltage to be dropped across the control device to compensate for the smaller voltage drop across the internal resistance of the set.

Four basic types of voltage regulating circuits are used in rectifier sets. The main difference between the circuits is in the type of control device used to regulate the output voltage. The four main types of control device are:

- Transductors.
- Regulating transformers.
- Thyristors.
- Saturable transformers.

Transistors are used in some battery eliminators used to power subs equipment. However, power losses prohibit their use in larger sets.

4.9 VOLTAGE REGULATING CIRCUIT USING A TRANSDUCTOR AS THE CONTROL DEVICE. Fig. 20 shows a typical rectifier set which uses a transductor as the control device.

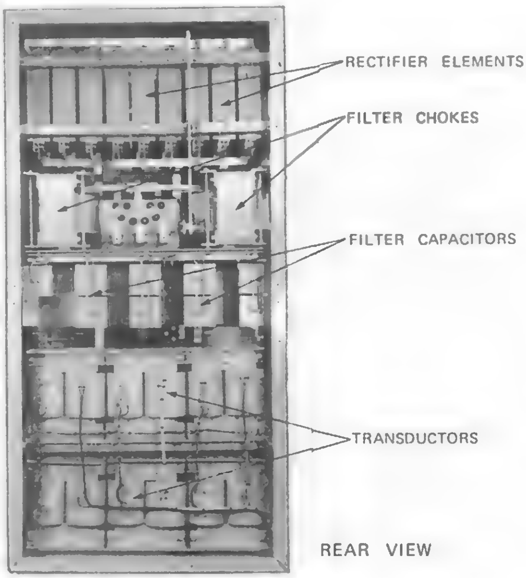


FIG. 20. TYPICAL RECTIFIER SET USING A TRANSDUCTOR AS THE CONTROL DEVICE.

Fig. 21 shows the principle of operation of this type of circuit. A sample of the output voltage is applied to a voltage comparison circuit together with a reference voltage. The reference voltage circuit provides a voltage which remains constant despite changes in external conditions such as load current, input voltage, and temperature. The voltage comparison circuit compares the output voltage of the rectifier set with the reference voltage, and derives a control signal the magnitude of which is proportional to deviations in the output voltage of the set. This signal is amplified, and controls the output voltage of the set by regulating the voltage drop across the transductor.

When the output voltage of the set deviates from its nominal value, the amplified control signal varies the voltage drop across the transductor to ensure that the output voltage remains within limits. The direct current amplifier allows a very small change in D.C. output voltage to be detected and corrected, making this type of regulating circuit very sensitive. The circuit compensates for all changes in D.C. output voltage, regardless of whether they are caused by changes in load, input voltage or frequency, or temperature. In some sets the transductor is connected between the secondary of the main transformer and the rectifier stack, instead of between the A.C. input terminals and the primary winding of the main transformer.

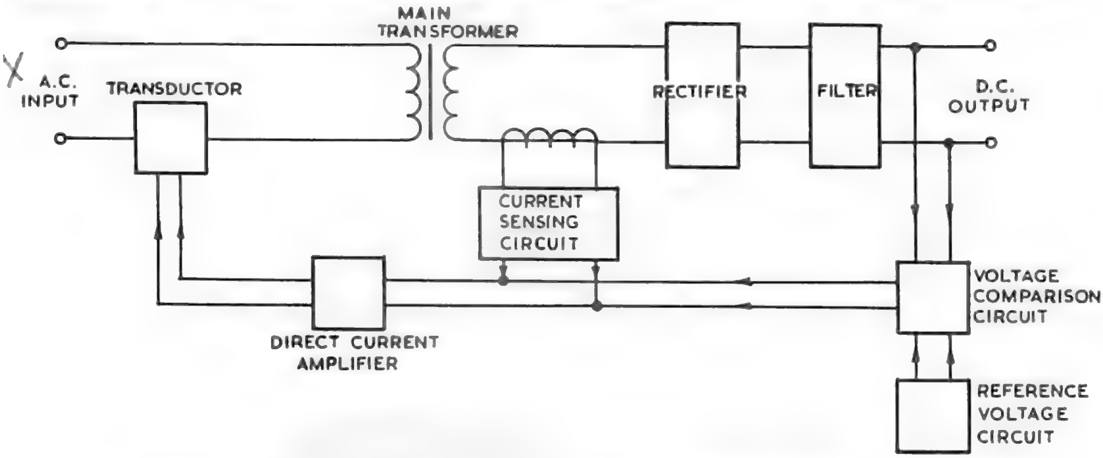


FIG. 21. BLOCK DIAGRAM OF A TRANSDUCTOR-REGULATED RECTIFIER SET.

4.10 VOLTAGE REGULATING CIRCUIT USING A THYRISTOR AS THE CONTROL DEVICE (Fig. 22). Fig. 23 shows the block diagram of a typical thyristor-regulated rectifier set. The thyristors replace two diodes in a normal rectifier bridge, and perform a rectifying function as well as the controlling function.

The circuit operates in the same way as the transductor-regulated set except for the addition of a trigger circuit between the D.C. amplifier and the control device. The output voltage of the set is regulated by controlling the point at which each thyristor triggers to the on state within its duty half cycle.

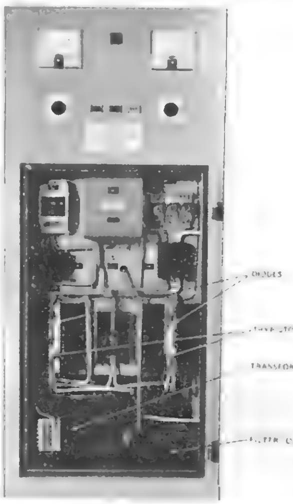


FIG. 22. TYPICAL RECTIFIER SET USING THYRISTOR AS THE CONTROL DEVICE.

For example, when the output voltage of the set decreases, the voltage comparison circuit detects the change, and modifies the signal applied to the trigger circuit in such a way as to cause the thyristors to trigger to the on state earlier in their duty half cycles. This corrects the output voltage by decreasing the average voltage across the thyristors.

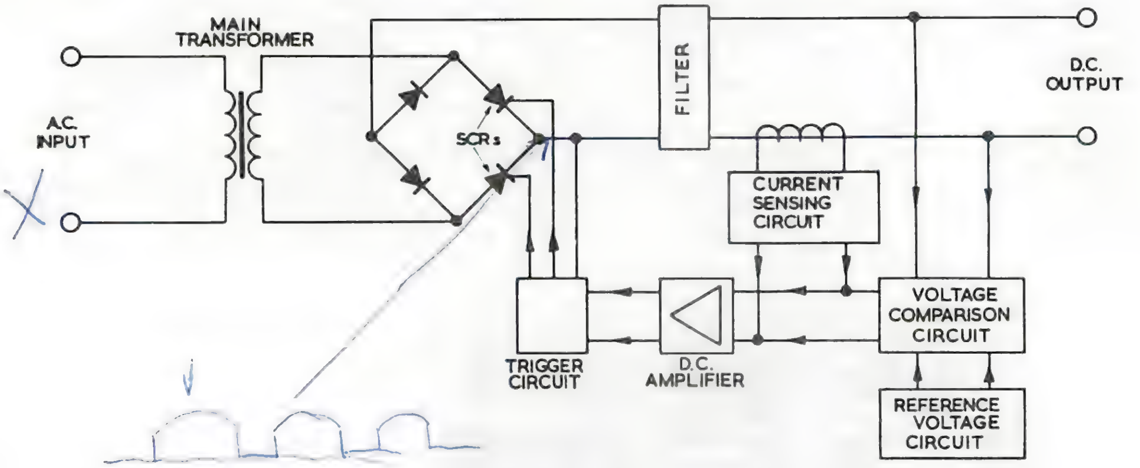


FIG. 23. THYRISTOR-REGULATED RECTIFIER SET.

4.11 VOLTAGE REGULATING CIRCUIT USING A REGULATING TRANSFORMER AS THE CONTROL DEVICE. Fig. 24 shows the principle of operation of a typical circuit of this type. The output voltage is regulated by injecting a voltage in series with the input to the main transformer. In most sets the circuit is arranged so that the injected voltage (buck-boost voltage) is either in phase or 180° out of phase with the input voltage.

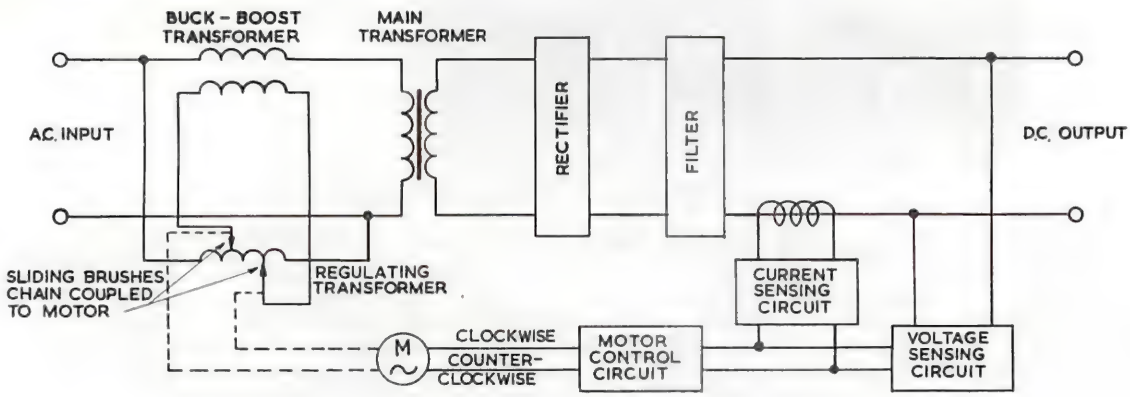


FIG. 24. TYPICAL RECTIFIER SET USING A REGULATING TRANSFORMER AS THE CONTROL DEVICE.

Control over the position of the sliding brushes, and therefore the output voltage of the rectifier set, is achieved by a circuit which senses the D.C. output voltage of the set, and governs the operation of a reversible motor. The circuit is designed so that a change in the output voltage causes the reversible motor to turn in such a direction as to restore the output voltage to normal. The sensing circuit stops the motor when the output voltage reaches the normal level.

When the input and injected voltages are in phase the two are additive and an increase in buck-boost voltage causes an increase in the output voltage. Conversely an increase in the buck-boost voltage when the two voltages are 180° out of phase causes a decrease in the output voltage.

The magnitude and phase of the buck-boost voltage are determined by the positions of sliding brushes on the regulating transformer, which in turn are controlled by a reversible motor. The motor drives these brushes in opposite directions so that at one extreme, the secondary voltage of the buck-boost transformer is at a maximum and in phase with the input voltage. At the other extreme, the secondary voltage of the buck-boost transformer is again at a maximum, but 180° out of phase with the input voltage. The brushes are mounted on opposite sides of the regulating transformer to allow them to cross over. The change from the in-phase condition to the out-of-phase condition occurs at the cross-over point. This is also the zero voltage point. Fig. 25 shows a typical suite containing two mechanically regulated rectifier sets.

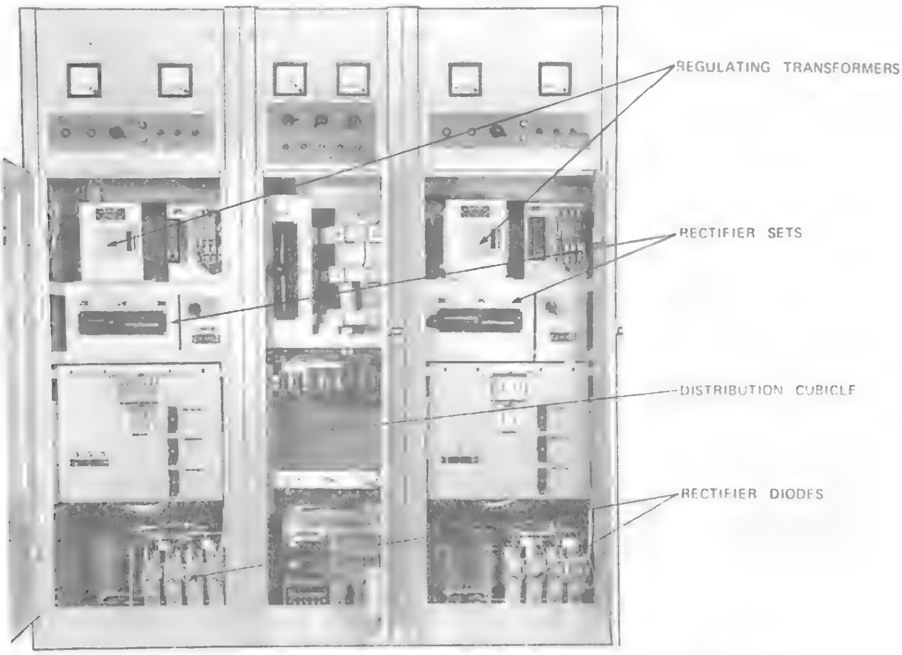


FIG. 25. MECHANICALLY-REGULATED RECTIFIER SETS.

4.12 VOLTAGE REGULATING CIRCUIT USING A SATURABLE TRANSFORMER. This type of voltage regulation is used on some small rectifier sets, and is dependent on the principle that when a transformer works into the saturated region of the B/H curve of its core its secondary voltage remains steady. In the typical circuit shown in Fig. 26, the capacitor and the primary winding of the transformer are designed to form a resonant circuit. The circulating current in this circuit ensures that the core of the transformer operates into saturation, and causes the secondary voltage of the transformer to remain steady despite changes in the A.C. input voltage.

To counteract changes in D.C. output voltage caused by load current variations, the output of the set is connected to the load terminals via a control winding of the saturable transformer. The flux produced by this winding varies the amount of effective flux linking the primary and secondary windings, and controls the secondary voltage of the transformer which in turn controls the output voltage of the set. The circuit is arranged so that an increase in load current increases the secondary voltage of the transformer to compensate for the increased voltage drop across the internal impedance of the set.

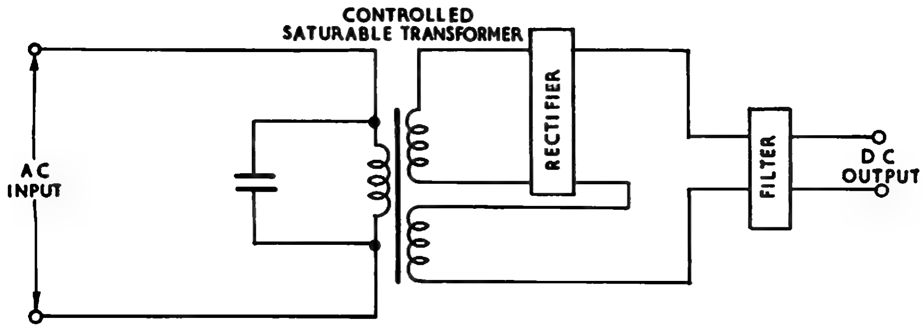


FIG. 26. TYPICAL RECTIFIER SET USING A
SATURABLE TRANSFORMER AS THE CONTROL DEVICE.

4.13 CURRENT LIMITING CIRCUIT. To ensure that components used in rectifier sets are operated within their rated limits, the maximum output current that can be drawn from a set is automatically limited to a safe value by a current limiting circuit. In most rectifier sets, current limiting is achieved by using the voltage control device to lower the output voltage when an attempt is made to overload the set.

For example, in Fig. 21 a current sensing circuit derives a signal which is proportional to the output current. When the preset current limit is exceeded, the signal from the current sensing circuit overrides the signal from the voltage comparison circuit, and applies a signal to the control device to lower the output voltage. The reduction in output voltage prevents the current from exceeding the maximum safe value.

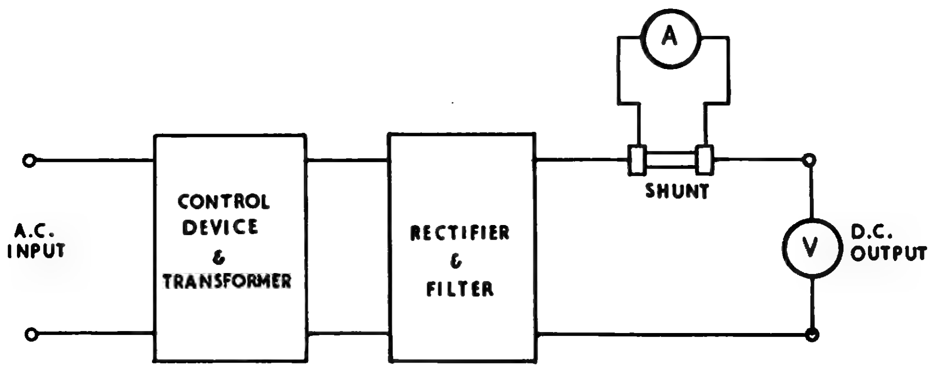


FIG. 27. MEASURING INSTRUMENT CIRCUIT.

4.14 MEASURING INSTRUMENT CIRCUIT. Rectifier sets are fitted with voltmeters and ammeters to facilitate monitoring of the output voltage and current. The typical circuit (Fig. 27) shows that the voltmeter is connected across the output of the set and that the ammeter is connected across a shunt connected in series with the output.

4.15 SWITCHGEAR CIRCUIT. Fig. 28 shows the switching arrangements of a typical rectifier set (the overall switching arrangements are given in Fig. 3). The A.C. input to the set is connected via isolator switch SWA and contactor CRA to the control device. The D.C. output of the set is switched by knife switch SWD, and the mode of operation is controlled by rotary switch SWC.

To place the set into service, the mode of operation switch (SWC) is operated to the appropriate position, the isolator switch (SWA) is closed, and light-duty A.C. switch (SWB) is operated to "On". Provided the control and alarm circuit contacts are closed, contactor CRA operates and energises the set.

Many other switching arrangements are used in rectifiers set, including arrangements which use contactors to switch the D.C. output of the set.

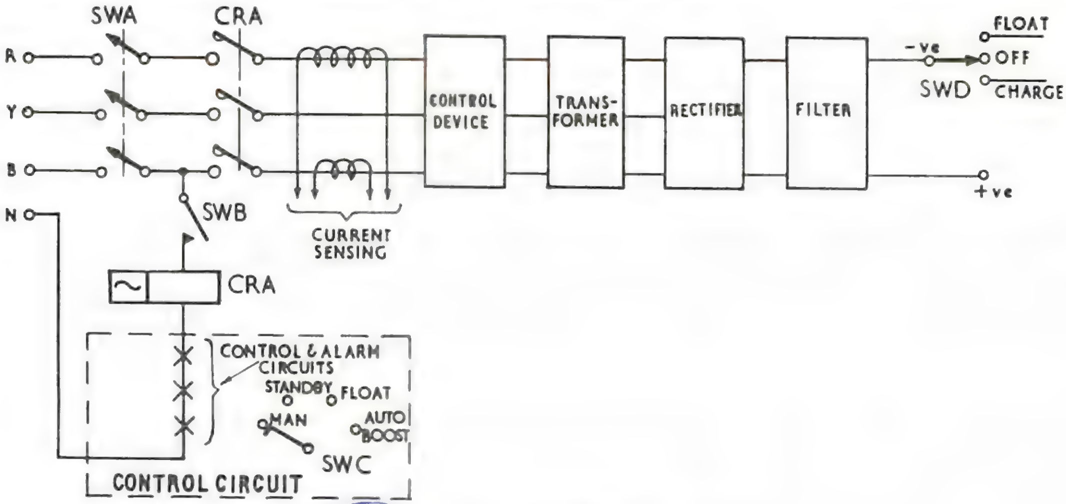


FIG. 28. TYPICAL SWITCHGEAR CIRCUIT.

4.16 TYPICAL RECTIFIER SET AND BATTERY INSTALLATION. Fig. 29 shows a typical rectifier set and battery installation.

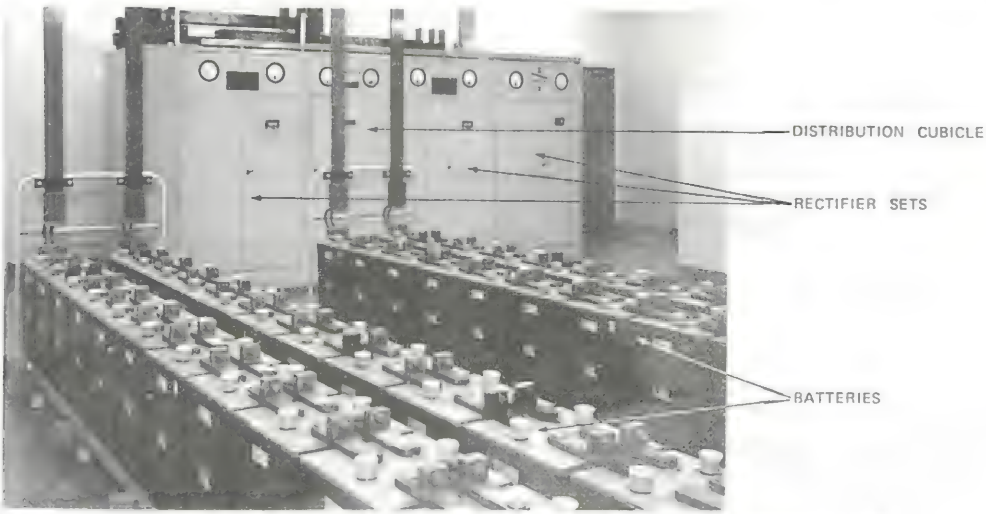


FIG. 29. TYPICAL RECTIFIER SET AND BATTERY INSTALLATION.

5. NON–MAINS INSTALLATIONS

5.1 GENERAL. Fig. 30 shows the block diagram of a typical non-mains D.C. no-break installation. This installation is used to supply power to broadband radio repeater stations in isolated areas and is one of several possible D.C. no-break installations. In other installations the wind generator is replaced by a second diesel engine, or, when wind conditions are particularly favourable and the power requirement is low, the wind generator may be the only primary source of power. In Fig. 30 the station load comprises:

- No-break load. This is a D.C. load and comprises telecom equipment requiring a D.C. no-break supply and D.C. lighting. A break in the power supply to equipment included in this load causes serious dislocation of communication services.
- Non-essential load. This is an A.C. load and comprises such things as A.C. lighting and power points for test equipment. This load is supplied with power only when the diesel generator is running.

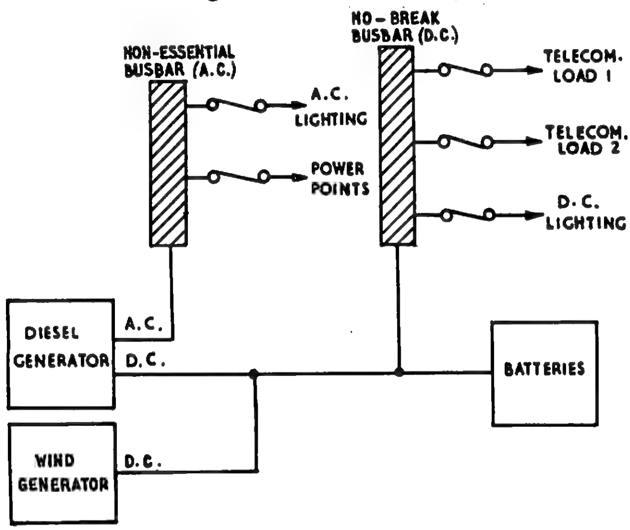


FIG. 30. TYPICAL NON-MAINS D.C. NO-BREAK INSTALLATION.

5.2 OVERALL OPERATION. In mains powered D.C. no-break installations the batteries and charging plant are operated under the float system. In non-mains installations the batteries and charging plant are operated under what is referred to as a cycling system. In this system the batteries are not maintained in a fully charged condition but are allowed to discharge to a predetermined level and then recharged.

Under favourable wind conditions the wind generator generates sufficient power to supply the load and provide a small charging current to the batteries. When the wind fails, the battery supplies the load until it is approximately 50% discharged as indicated by a voltage sensing unit. The voltage sensing unit provides an "engine start" signal at the 50% discharge point, causing the diesel generator set to start. The generator supplies the load and recharges the battery until the battery is approximately 83% charged. At this stage a "diesel stop" voltage sensing circuit applies a signal to the control circuit to initiate close down of the diesel generator. The engine is allowed to run on for a period which is controlled by an adjustable timer. At the end of this period the diesel engine is stopped and another cycle begins. The time duration of the discharge part of the cycle is dependent on the power supplied by the wind generator which in turn is dependent on wind conditions.

Voltage regulators control the output voltage of the wind generator and the diesel generator to ensure that the voltage applied to the telecom equipment is maintained within limits.

5.3 FACILITIES. The facilities provided by the installation shown in Fig. 30 are:

- Maintenance of a continuous D.C. supply to the no-break load.
- Provision of an A.C. supply during periods when the diesel generator is running.
- Automatic cycling of the batteries under the control of voltage sensing circuits, using the diesel generator and the wind generator as primary sources of power.
- Automatic shutdown of the diesel engine and provision of an alarm under the following conditions:
  - Failure of the generator.
  - Failure to start.
  - Generator overvoltage.
  - Engine overheated.
  - Oil pressure low.
  - Fuel empty.
- Provision of an alarm under the following conditions:
  - Fuse operated.
  - Selector or control switch off-normal.
  - Battery volts high or low.
  - Fuel low.
- Remote starting and stopping of the diesel generator from a control station.
- Manual switching to permit boost charging of batteries and testing of generators, batteries, and control equipment.
- Manual switching and connecting facilities to permit connection of emergency D.C. and A.C. power supplies.
- Metering of voltage and current at the load and boost busbars and the outputs of the generators and batteries.

5.4 GENERAL DESCRIPTION. The single line diagram (Fig. 31) shows all switches in the normal position. Under these circumstances both batteries and both generators are connected in parallel to the load. A filter eliminates ripple from the D.C. output of the generators.

5.5 DIESEL ENGINE STATIONARY – BATTERY MORE THAN 50% CHARGED. Under these conditions the load is supplied either from the battery or the wind generator, depending on wind conditions. When wind conditions are favourable, the wind generator supplies the load and provides a small charging current to the battery. The magnitude of the charging current depends on the difference between the output current of the generator and the load current. When the wind velocity decreases to a point where the wind generator voltage decreases to a value below the battery voltage, the battery discharges and supplies the load. If the light wind conditions persist, the battery reaches a point where its voltage indicates that it is 50% discharged.

5.6 ENGINE STARTING – BATTERY 50% DISCHARGED. At the 50% discharged point the "engine start" voltage sensing circuit applies a start signal to the diesel engine. The engine starts and runs up to operating speed. Since the output of the diesel generator is normally connected in parallel with the battery, no mechanical switching is necessary to allow the generator to supply the load and charge the battery. Up to three separate attempts, each lasting ten seconds, can be made to start the engine.

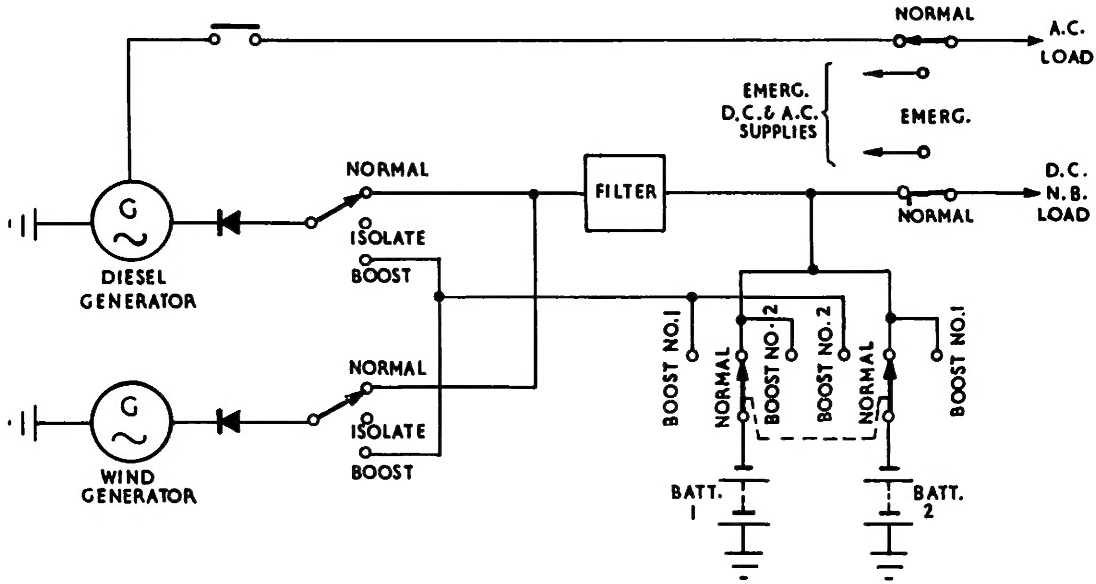


FIG. 31. TYPICAL D.C. NO-BREAK INSTALLATION (NON MAINS).

5.7 ENGINE RUNNING – BATTERY 83% CHARGED. To allow the voltage sensing circuits to use the battery voltage as an accurate indicator of the state of charge of the batteries, it is necessary to inhibit the output of the wind generator during periods when the diesel engine is running. This is achieved by inserting extra resistance in the field winding of the wind generator.

When the battery voltage reaches a point where it is 83% charged, the "engine stop" voltage sensing circuit applies a signal to the engine control circuit to initiate close down of the diesel generator. At this stage a run-on timer takes control of the circuit and allows the diesel generator to run on and supply the load until a preset time has expired. After this time has expired the fuel supply to the engine is cut off and the diesel generator stops. The wind generator is allowed to supply the load again and another cycle begins.

5.8 BOOST CHARGING OF BATTERIES. Before a battery is disconnected from the load for boost charging, both batteries are cycled to the point of maximum charge. This ensures that one battery is capable of supplying the load while the other battery is disconnected for boost charging.

To boost charge battery number 1 the battery selector switch is operated to "Battery Boost No. 1" and the diesel generator switch to "Boost". Under these conditions battery number 1 is connected to the output of the diesel generator via the boost busbar and battery number 2 supplies the load. A regulator switch associated with the diesel generator is operated to "Boost" to provide a suitable boost charge characteristic from the generator. The battery selector switch is operated to "Battery Boost No. 2" when battery number 2 is to be boost charged.

5.9 EQUIPMENT LAYOUT. Figs. 32 and 33 show a typical overall equipment layout and photographs of the diesel generator set and the control cubicle respectively. The wind generator is mounted on a tower at a suitable distance from the equipment building. In this installation the station battery is used to start the diesel engine and a separate control and starter battery is not required: The station battery is mounted on a stand. Note that the diesel engine is skid mounted to enable changeover of the engine-generator in the shortest possible time. Provision is made for the installation of a second diesel generating set.

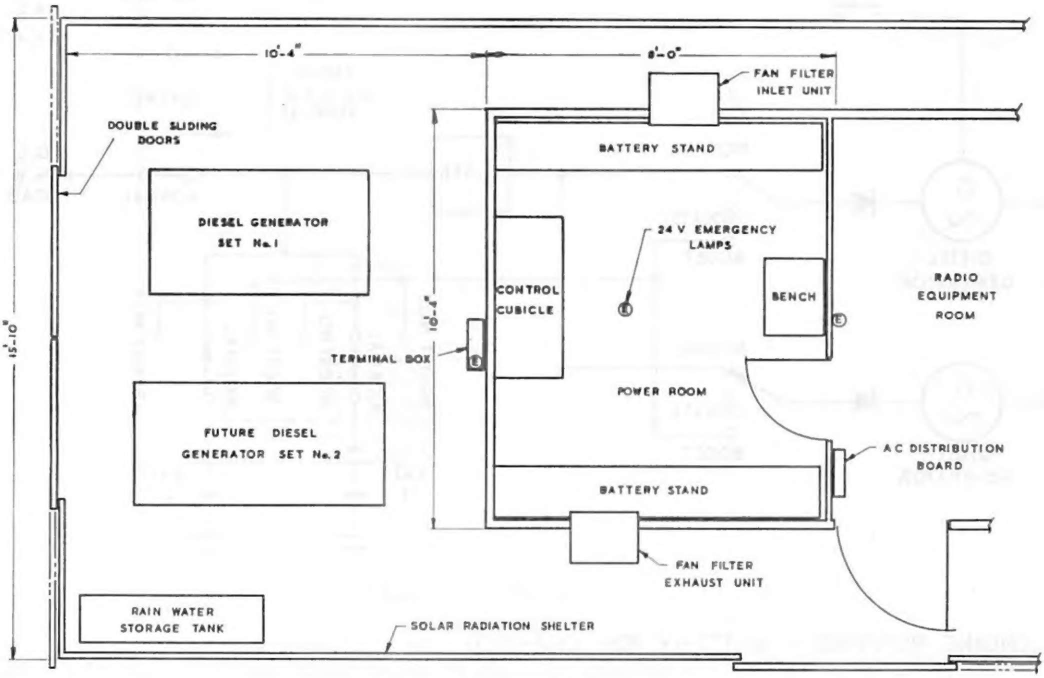


FIG. 32. EQUIPMENT LAYOUT.

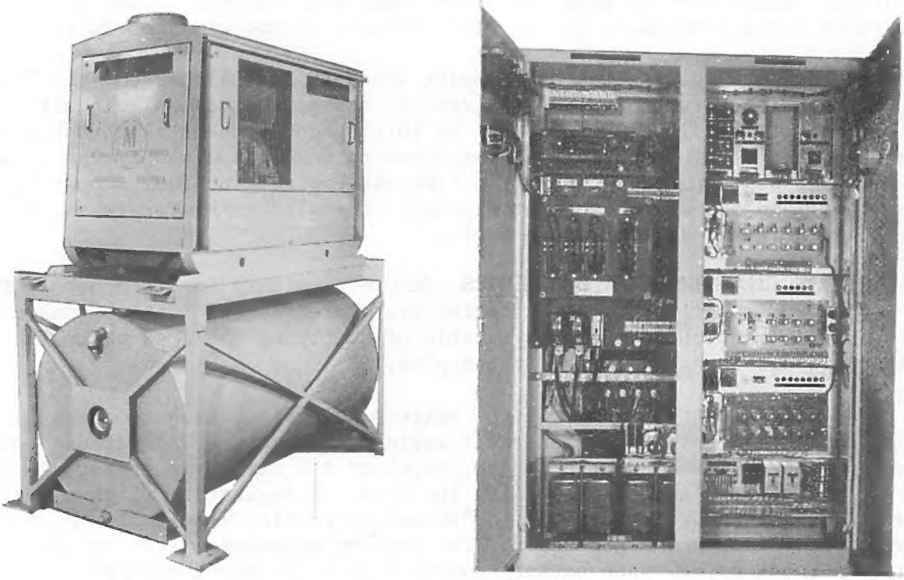


FIG. 33. DIESEL GENERATOR SET AND CONTROL CUBICLE.

5.10 DIESEL GENERATOR. Both the diesel generator and the wind generator are of the brushless type. The principle of operation of the diesel generator is the same as that of the brushless alternator (see para. 3.6), except for the addition of a full wave rectifier which converts the output to D.C. The diodes used for this purpose are mounted on the frame of the generator.

The diesel generator has a second set of output windings wound in the stator slots. The purpose of the extra set of windings is to provide a 240 V A.C. power supply.

5.11 WIND GENERATOR. The main source of power at the type of station shown in Fig. 30 is the diesel generator. The wind generator is an auxiliary source which reduces the number of engine starts and the total engine running time by supplying the load and charging the batteries as wind conditions permit.

The generator, gearbox (ratio 5:1), and propellor are mounted on a steel tower 40 ft. high. The propellor, which is of the "variable-pitch" type, is prevented from overspeeding by a centrifugal governor which changes the blade pitch, thus controlling the rotational speed. A magnetic latching device inhibits the action of the centrifugal governor up to wind speeds of 30 m.p.h., thereby ensuring that the action of the governor does not reduce the output of the machine up to this wind speed.

As shown in Fig. 34 the principle of operation is similar to the brushless machine used on the diesel generator. The slip rings shown in the D.C. output and the regulator connection are associated with the generator mounting arrangement which allows the propellor to turn into the wind (as determined by the wind direction).

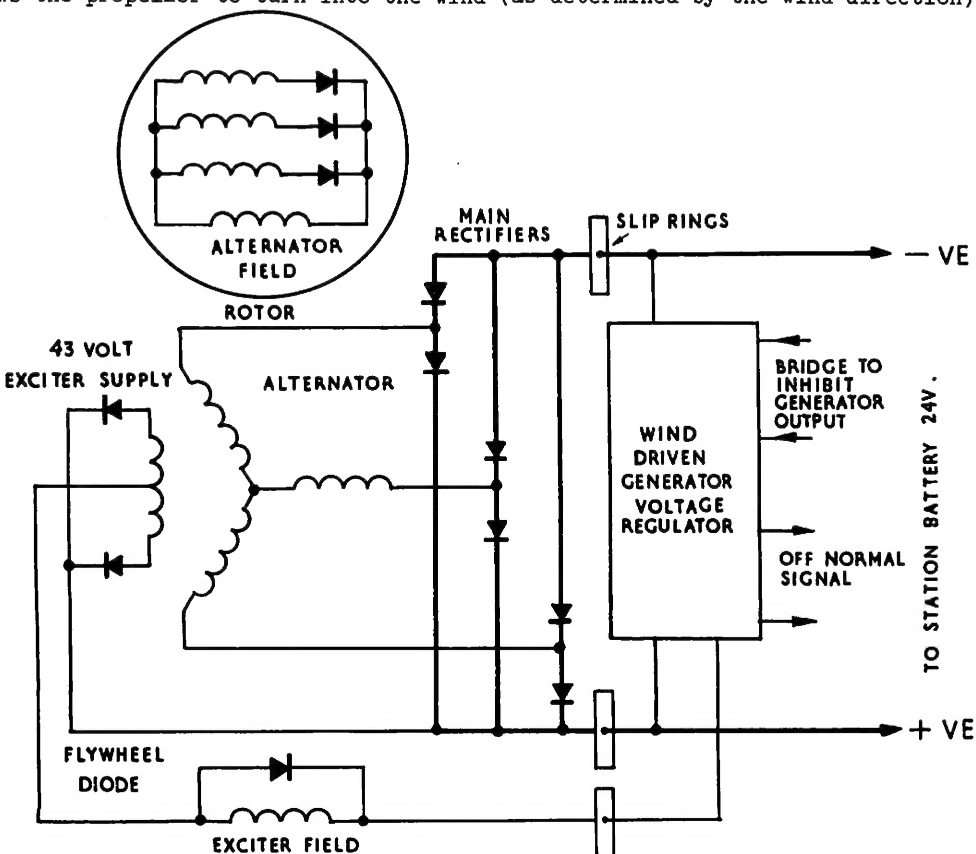


FIG. 34. PRINCIPLE OF THE WIND GENERATOR.

6. TEST QUESTIONS

1. *List the three types of power load to be found at a typical mains powered D.C. no-break installation and briefly describe each load.*

2. *With the aid of a single line diagram briefly describe the overall operation of a typical mains powered D.C. no-break installation (include two rectifier sets in your diagram).*

3. *What is meant by the term "load sharing"?*

4. *Explain the differences between the "float" and "cycle" systems of operating storage batteries.*

5. *What are the float voltage limits for a 24 cell battery installation using lead-acid cells?*

6. *List the three main reasons for earthing one pole of telecom D.C. power installations.*

7. *List six facilities provided by a typical N.S. set.*

8. *With the aid of Fig. 5 briefly describe the operation of the N.S. set from the time the mains supply fails till the time power is restored to the essential busbar.*

9. *Briefly explain the principle of operation of a brushless D.C. generator.*

10. *With the aid of a block diagram, explain the basic operation of an alternator regulator.*

11. *Why are diesel engines preferred over petrol engines for use in N.S. sets?*

12. *Why is it important to have individual hydrometers for lead-acid and nickel-cadmium batteries?*

13. *List six facilities provided by a typical rectifier set.*

14. *Briefly describe the functions of the following rectifier set sub-circuits:*
    - *Transformer circuit.*
    - *Filter circuit.*
    - *Rectifier circuit.*
    - *Voltage regulating circuit.*
    - *Current limiting circuit.*

15. *Draw a full-wave rectifier circuit using a three phase transformer with its secondary connected in the star configuration.*

16. *With the aid of a block diagram explain the principle of operation of a voltage regulating circuit associated with rectifier sets.*

17. *With the aid of a block diagram explain the overall operation of a typical non-mains D.C. no-break installation.*

18. *With the aid of Fig. 31 explain the switching arrangements necessary to boost charge a battery at a typical non-mains power installation.*

END OF PAPER.